THE INTERNATIONAL LUNAR NETWORK (ILN) ANCHOR NODES MISSION UPDATE. B. A. Cohen[1], J. A. Bassler[1], J. M. McDougal[1], D. W. Harris[1], L. Hill[1], M. S. Hammond[1], B. J. Morse[2], C. L. B. Reed[2], K W. Kirby[2], T. H. Morgan[3], the ILN Science Definition Team, and the MSFC/APL ILN Engineering Team. [1]NASA Marshall Space Flight Center, Huntsville AL 35812 (Barbara.A.Cohen@nasa.gov); [2]The Johns Hopkins University Applied Physics Laboratory, Laurel MD 20723; [3]NASA Headquarters, Washington DC 20546.

Introduction: NASA's Science Mission Directorate (SMD) established the Lunar Quest Program (LQP) to accomplish lunar science objectives embodied in the National Academies report The Scientific Context for Exploration of the Moon (2007) and the NASA Advisory Council-sponsored Workshop on Science Associated with the Lunar Exploration Architecture (2007). A major element of LQP's lunar flight projects is the International Lunar Network (ILN), a network of small geophysical nodes on the lunar surface. NASA plans to provide the first two stations around 2014 and a second pair in the 2016-2017 timeframe. International involvement to provide additional stations will build up the network so that 8-10 nodes could be simultaneously operating. This flight project complements SMD's initiatives to build a robust lunar science community through R&A lines and increases international participation in NASA's robotic exploration of the moon.

Mission Science: The moon provides an important window into the early history of the Earth. Its interior is a treasure-trove of information about its initial composition, differentiation, crustal formation, and subsequent magmatic evolution. In spite of more than four decades of intensive study, many aspects of the moon, especially detailed information about its interior, remain to be determined. Geophysical measurements provide the optimum means of obtaining this essential information.

A global geophysical network has been a science community desire since the Apollo seismic stations were turned off in 1977. The science motivation has been detailed in numerous community and independent reviews, reports and recommendations [most recently, 1-4]. The next generation of geophysical measurements on the moon must improve upon data obtained during the Apollo missions by the Apollo Lunar Surface Experiment Packages (ALSEPs) deployed at the landing sites. Valuable as these data are, in most cases they have significant limitations that can be overcome by the deployment of more advanced geophysical instruments. The goal of a lunar geophysical network is to improve our understanding of the interior structure and composition of the moon.

The ILN Anchor Nodes Science Definition Team (SDT) examined the opportunities and challenges associated with implementing a next-generation lunar geophysical network. The SDT recommended that the scientific objectives of the US contribution to the ILN, in order of priority, should be:

1. Understand the current seismic state and determine the internal structure of the moon.
2. Measure the interior lunar heat flow to characterize the temperature structure of the lunar interior.
3. Measure the electrical conductivity structure of the lunar interior.
4. Use laser ranging to determine deep lunar structure and conduct tests of gravitational physics.

The SDT considered different experiments that would be most useful for probing the lunar interior and defined precision and accuracy of the measurements needed to achieve the science goals. The intention of this study is not to prescribe the exact payload for either the International Lunar Network or for the Anchor Nodes themselves, but rather to explore several ways that measurements of the deep lunar interior may be accomplished and to outline the sensitivities needed to achieve those goals. The SDT concluded that seismometry is the essential element of any surface network, being enabled by simultaneously-operating stations and best able to address the highest-priority science goals of a lunar geophysical mission. Direct measurement of the lunar heat flow, electromagnetic sounding, and next-generation laser ranging are desirable measurements that provide additional information at each site about the shallow substructure and deep interior.

Mission Implementation: NASA's Science Mission Directorate and Exploration Systems Mission Directorate (ESMD) are providing the first two stations of the ILN, called the Anchor Nodes. These two US stations may not necessarily be the first to become operational on the lunar surface, but are the first committed and planned missions to contribute to the ILN. The mission is a Class-D, directed mission jointly implemented by NASA Marshall Space Flight Center (MSFC) and the Johns Hopkins University Applied Physics Laboratory (APL), with contributions from JPL, ARC, GRC, DOD, and industry.

The Anchor Nodes project is currently completing pre-Phase A activities. MSFC and APL generated eight different mission concept design studies and presented the results to SMD, including detailed concept engineering analysis and parametric cost estimates. The team conducted extensive design trades, including hard and soft landers and penetrators, solar array/battery and nuclear (ASRG and derivative ASRG technology) options, and multiple launch configurations and launch vehicles. The project expects a Mission Concept Review in spring of 2009, carrying two options that meet the SDT requirements while providing flexibility to NASA in budget phasing and technology development. Nuclear power sources enable design of the lowest mass landers, which could be configured on multiple launch vehicles (2, 3 or 4 landers on an Atlas V 401; 2 landers on a Taurus II or Falcon 9). However, the project schedule is then driven by the ASRG development schedule and also incurs costs related to nuclear launch certification. Alternatively, if the payload can be made sufficiently low-powered, landers using solar arrays and batteries could accomplish the mission. These lander designs are more massive (2 on an Atlas V) but are the lowest-cost design and could launch by 2014. In all the trade studies, the launch vehicle cost is the major driver of mission costs.

A set of risk reduction tests and activities have been identified and funded to support development of the ILN lander. Engineering tasks include propulsion thruster testing in collaboration with the Missile Defense Agency; propulsion thermal control testing and demonstration; composite coupon testing and evaluation; landing leg stability and vibration; demonstration of landing algorithms in a lander testbed; and understanding how candidate experiments might be deployed from the lander and the effects on the various measurements that deployment under or to the side of a small lander might have (e.g. lander dampening of seismic signals, lander-induced vibrations picked up by a seismometer, daily shadowing of the surface, vibrational and electromagnetic characteristics of an ASRG, etc.).

Some of these activities will take place in the MSFC Lunar Lander Robotic Exploration Testbed, which was recently established in support of risk reduction testing to demonstrate ILN capabilities. The MSFC test facility is currently operational and has been proved out using a Hover Test Vehicle from ARC. An MSFC test vehicle using an Anchor Nodes-like design is under construction, which will allow demonstration of control software. Both the current Ames HTV and MSFC vehicle utilize a compressed air propulsion system, but a second version of the MSFC vehicle is planned that will utilize an alternate propulsion system for longer duration flight and descent testing. The upgraded test vehicle will also integrate flight-like components for risk reduction testing, such as landing sensors (cameras, altimeters), instruments, and structural features (landing legs, deployment mechanisms).

An Instrument RFI was released in December 2008. Twenty-eight responses were received from industry, academia, NASA centers, international partners and other government agencies. The intent of the RFI analysis is as a reality check to the mission design concepts, providing assessment of the scientific merit, proposed instrument readiness level, and necessary deployment and interface accommodations. The project acquisition strategy will be formulated during the Pre-Phase A studies and submitted to HQ/SMD for approval. The Anchor Nodes payload is expected to be competed through an Announcement of Opportunity process in 2009.

International Participation: Representatives from space agencies in Canada, France, Germany, India, Italy, Japan, the Republic of Korea, the United Kingdom, and the United States agreed on a statement of intent in July of 2008. The statement marked an expression of interest by the agencies to study options for participating in the ILN. The statement of intent does not completely define the ILN concept, but leaves open the possibility for near and long-term evolution and implementation. Initially, participants intend to establish potential landing sites, interoperable spectrum and communications standards, and a set of scientifically equivalent core instrumentation to carry out specific measurements.

Summary: The concept of an International Lunar Network provides an organizing theme for US and International landed science missions in the next decade by involving each landed station as a node in a geophysical network. Each ILN node will carry a core set of instruments to make measurements requiring broad geographical distribution on the moon. Creation of such a network will dramatically enhance our knowledge regarding the internal structure and composition of the moon, as well as yield important knowledge for the safe and efficient construction and maintenance of a permanent lunar outpost.

References: [1] M. A. Wieczorek, et al. (2006) *Rev. Min. Geochem.* 60, 221-364. [2] *The Scientific Context for Exploration of the Moon: Final Report*, NRC Space Studies Board, 2007. [3] *Workshop on Science Associated with the Lunar Exploration Architecture*, Tempe, Arizona, 2007. [4] *Opening New Frontiers in Space: Choices for the Next New Frontiers Announcement of Opportunity*, NRC Space Studies Board, 2008.